FEL/SPI Cosmo-Geochemical Applications

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ALFF Workshop
Argonne National Laboratory
October 30-31, 2003

FEL/SPI Cosmo-Geochemical Applications

Top Level; Define FEL/SPI?

I. Multi-element Trace Element Microprobe

- **Stardust Applications**

II. Microprobe Organic Molecular Characterization.

- **Meteoritics Applications**
- **Stardust Applications**
- **Geochemical Applications**

III. Special Targets for Isotopic Analysis.

- **N microprobe**
- **Stardust Reconnaisance**

Multi-Element Trace Element Microprobe

- **Tune FEL to C FIP;**
- **Photon Energy > FIP for all other rock-forming elements.**
- **Use F2 laser between FEL pulses to enhance sensitivity.**

Application similar to TOF-SIMS, but with significant improvement.
TOF-SIMS does not play a major role in ET material analysis.

Limitations of TOF-SIMS

A. Low sensitivity because of low duty cycle.

B. Low sensitivity because of low sputtering rate.

C. Low sensitivity because of low ion yields

- **Rely on sputter ions (as opposed to atoms for FEL/SPI)**
- **Low secondary ion yields for many elements, even allowing for both positive and negative secondary applications**

D. Molecular Interferences

E. Quantitation lots of work?

Multi-element Trace Element Microprobe

Gains with FEL/SPI over TOF-SIMS:

A. Duty Cycle: still an issue. F2 laser should help.

B. Low sputtering rate overcome with atomization by laser ablation

Erosion rates might be hard to control with small grains.

C. Using atoms instead of secondary ions a big gain.

D. Molecular interferences could be a big issue:

FEL/SPI must have sufficiently high photon power density to break up molecular ions -- key to success with this application.

E. If nearly 100% ionization possible (as advertised) then relative counts equals relative abundance -- a big advantage.

Assumes that transmission is mass independent, or that fractionation known.

Multi-element Trace Element Microprobe

Stardust Applications

- **Up to 100 micron grains from coma of Wild 2 comet captured in aerogel.**
- **Both silicate and refractory carbonaceous grains expected. Consider silicates here.**
- **Analyze as received or as circa 1-5 micron microtomed section.**
  - **Hemisphere of fused aerogel must be avoided.**
- **FEL/SPI niche must be trace elements.**
  - **Have SEM for major elements (quantitation?)**
- **Powerful ANL/UC consortium for elemental analysis?:**
  - **SEM**
  - **EDS/SXRF at APS**
  - **FEL/SEI**

Microprobe Organic Molecular Characterization

- **Must be able to operate FEL/SPI in mode which minimizes molecular fragmentation.**
  - **Opposite to requirement to destroy molecules for trace element analysis.**
  - **Relief: not clear what "molecule" means for highly polymerized refractory carbon --- may be better to talk about distribution of organic functional groups or macromolecular structure of polymer.**

Microprobe Organic Molecular Characterization

Meteoritic Application

- **Carbon chemistry of carbonaceous chondrites has been extensively studied**
- **Little data on in-situ molecular distribution**
  - **e.g. data on bulk concentrations of amino acids, but don't know where they are in sample. Presumably associated with elemental C, but might be different kinds of elemental C**

Microprobe Organic Molecular Characterization

Stardust Application

- **Expect large numbers of refractory carbonaceous grains.**
- **Lack a general way to characterize these on a molecular scale.**

  Not clear what TEM will show on these grains.

Microprobe Organic Molecular Characterization

Geochemical Application (A. Sessions, CalTech)

Biomarkers in Archean Rocks.

Rocks have C, but not clearly biogenic.

Proposed molecular biomarkers: sterane, hopenone

- **Lipid decomposition products; MW ≈ 400.**

Measured in bulk samples by GC/MS, but can't prove that they're not contaminants.

Use spatial resolution of FEL/SPI to show that these molecules found associated with reduced carbon and not with silicates.

Vary photon energy above and below biomarker FIP to prove identification.

Special Targets for Isotopic Analysis.

- **Many geochemical problems require isotopic ratio precision in the part per 1000 or better.**
- **RIMS analyses have odd-even mass fractionations which make high precision isotopic analyses difficult.**
- **FEL/SPI may not have such fractionations.**
- **Nevertheless, with multichannel plates, TOF mass spec has dynamic range problems for high precision isotopic ratios.**

Special Targets for Isotopic Analysis

- **N isotopic variations range over factor of 2 in planetary materials.**
  - **Origin of variations not known.**
- **Microdistribution data important to understanding.**
- **Serious SIMS competition, but must use CN negative molecular ions.**
  - **Can't study N without C.**
- **N, but not C, opportunities.**
  - **Iron Meteorites**
  - **N-bearing glass inclusions in meteoritic olivines.**

Special Targets for Isotopic Analysis

Stardust Reconnaisance

- **Comet Wild-2 believed to represent Kuiper Belt object.**
- **First look at material formed beyond 50 AU in solar system.**
- **Such material might have escaped the isotopic homogenization which characterizes inner solar system material.**
- **Proportions of presolar materials with large (up to x10) isotopic variations could be large.**
- **May not have spatial resolution to compete with NanoSims, but this might not be important .**
- **FEL/SPI can survey many elements to see which elements and which grains have large (>1%) isotopic anomalies.**